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Navigation Results From Prototype Components of an Automated Real-Time Spacecraft Navigation System

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Abstract

At present, ground navigation support for interplanetary spacecraft requires human intervention for data pre-processing, filtering, and post-processing activities; these actions must be repeated each time a new batch of data is collected. ARTSN, the Automated Real-Time Spacecraft Navigation system, is a prototype of a software system for spacecraft navigation and monitoring; it has served as a bridge between the current legacy software and more fully automated spacecraft navigation systems that are in the planning stage. It has established new paradigms for deep-space navigation operations by introducing new capabilities to the deep space navigation analyst:

- *Real-time monitoring of spacecraft and tracking station performance through radio metric Doppler and range data*
- *Automated radio metric data validation and correction*
- *Real-time orbit and target updates*
- *"One step" access to trajectory, observable, filter, and mapping information*

orbit determination
automation
filtering

The ARTSN prototype components (data pre-processor, a shell interface, an engine, and data displays) are described in the paper. To date, there have been several demonstrations of ARTSN's capabilities using several deep space missions:

- *Mars Pathfinder.* ARTSN's first 'real world' tests were performed with Mars Pathfinder tracking data. The objective was to produce current state and epoch state solutions over a 76 day data arc. These solutions were then used to make encounter estimates; in both modes the ARTSN estimate agreed with that generated by the Pathfinder navigation team to less than half of the Pathfinder estimate uncertainty, which is suitable for station predict generation and maneuver design. A demonstration was also performed using an unedited recording of tracking data from the final two weeks of Mars Pathfinder before entry into the Martian atmosphere; this time span included the final trajectory correction maneuver.
- *Mars Global Surveyor.* The Mars Global Surveyor (MGS) navigation team demonstrated real-time navigation using ARTSN during the Mars Orbit Insertion (MOI) on September 11, 1997, and during the aerobraking phase of the mission to date. Streams of observable and residual values have been piped to several displays in real-time, both to the public and the navigation analysts themselves. The ARTSN pre-processor (ARDVARC) is of special use to the MGS navigation team. The resumption of aero-braking in the fall of 1998 required the rapid turn-around of navigation solutions as the mapping orbital period is reduced. ARDVARC's ability to correct and create tracking data files (for use with the current operational JPL navigation software) in real-time significantly reduced the latency between the time the data was received and the time the analyst could begin working.
- *Near Earth Asteroid Rendezvous (NEAR).* In January 1998 the real-time display of ARDVARC was used to observe a small maneuver performed by the NEAR spacecraft. Output from the ARDVARC graphical display was used by the NEAR navigation team at JPL to notify the project that the maneuver had been executed. Several parameters were changed in real-time to provide the analysts with the most information; this ability to change the processing configuration in real-time has proven invaluable. A month later, there was an opportunity to observe six thruster firings by the NEAR spacecraft. An annotated plot showing the results of this monitoring, along with the Δ-V assessments, was prepared seconds after the end of the data arc.

The ability of the ARTSN engine to be remotely commanded and updated is also being used for research into new navigation algorithms. For example, adaptive filter model tuning has been performed by integrating a filter bank consisting of several ARTSN engines with a gating network and an implementation of a genetic algorithm.

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